A TOOL FOR ESTIMATING EFFECTS OF LAND-USE CHANGES ON LOUISIANA BLACK BEAR HABITAT

Final Report

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INTRODUCTION

More than 80% of the bottomland hardwood forests in the Mississippi alluvial plain have been lost to land clearing for agriculture and those that remain are extremely fragmented (Neal 1990). As a consequence, Louisiana black bear populations (*Ursus americanus luteolus*) in the region exist only in isolated remnants of woodland associated with the Tensas River, the upper Atchafalaya River, and along the coast of Louisiana. Black bears are susceptible to habitat fragmentation (Hellgren and Maehr 1992, Hellgren and Vaughan 1994, Rudis and Tansey 1995, Pelton and van Manen 1997, Larkin et al. 2004, Clark et al. 2006) and, consequently, bear habitat in Louisiana is thought to be limited in quantity, quality, and spatial integrity. Furthermore, these isolated bear populations are vulnerable to chance demographic or environmental events because small and isolated populations may have low genetic diversity. In 1992, the Louisiana black bear was designated as threatened under the U.S. Endangered Species Act (USFWS 1992).

The subpopulations of black bears in Louisiana each occupy slightly different habitat but have similar vulnerabilities. The northern subpopulations (Tensas River Basin and the majority of the Upper Atchafalaya including the Red River State Wildlife Management Area) exist in isolated fragments of bottomland hardwood forests and have access to extensive agricultural production (primarily corn). Lands those bears inhabit are in federal, state, and private ownership. The bear subpopulation along the Louisiana coast (Lower Atchafalaya Basin) lives in a matrix of bottomland hardwood forests, cypress-tupelo forests, and emergent wetland. The coastal black bear population is centered on what is now Bayou Teche National Wildlife Refuge, which was created in 2001 to conserve the Louisiana black bear (Fig. 1; All figures and tables are found at the end of the Literature Cited section), but bears inhabit extensive private lands as well. Nyland (1995) evaluated coastal habitat use and reported that upland hardwoods were preferentially used year round, but were especially important during autumn. Benson and Chamberlain (2007) evaluated the Tensas bear population and reported that bottomland hardwoods were preferred by females. In general, bottomland hardwood forest cover, corn agriculture, and the lack of human disturbance seem to determine where bears can survive in Louisiana.

One of the primary objectives of the Louisiana black bear recovery plan is protection of habitat and interconnecting corridors of at least 2 of the subpopulations (USFWS 1995). Habitat loss is a significant threat to the species and the Atchafalaya Basin continues to experience rapid population growth and conversion from natural cover to agriculture and urban land use. The authority to address habitat loss is conferred to the USFWS through critical habitat designation and Section 7 of the Endangered Species Act and must be based on the best available science. Thus, the USFWS requires an objective, quantitative method to evaluate bear habitat throughout the state.

The objectives of our study were to develop a Geographic Information System (GIS)-based habitat model for the state of Louisiana and to develop a tool for evaluating the potential effects of various land-use changes on Louisiana black bears. We used a habitat model previously developed to assess habitat impacts of Hurricanes Katrina and Rita on the coastal black bears in Louisiana (Murrow et al. 2012) as the starting point of the analysis for this study. We augmented that dataset with telemetry locations collected from 1993 to 2010 to extend and modify the original coastal model which was based on the Mahalanobis distance (D^2) statistic. Our goal was to then use that model to develop an estimator and user-friendly interface based on ArcMap™ 10.1 software for recalculating relative habitat gain or loss when landscape changes occur (e.g., construction of roads, urbanization, and habitat restoration).

STUDY AREA

We evaluated the entire state of Louisiana while concentrating on the 3 units designated by USFWS as critical bear habitat (Figs. 1 and 2). Most of Louisiana is Outer Coastal Plain Mixed Forest followed by Lower Mississippi Riverine Forest (USFS 2004). The surface of the state can be divided into the uplands in the north and the alluvial region along the coast. The uplands consist of prairie and woodlands whereas the alluvial region includes swamps, coastal marshes and beaches, and barrier islands (Chapman et al. 2004). Elevations range from sea level at the coast, to 15–18 m at the prairie and alluvial lands, to Driskill Mountain in the uplands (163 m). The riverine system is extensive, consisting of >6,400 km of navigable waterways. Louisiana has a humid subtropical climate, with long, hot, humid summers and short, mild winters. Average annual temperatures ranged from 16 to 21ºC. Rainfall was abundant and well distributed throughout the year; precipitation ranged from 102 to 153 cm annually. In more elevated areas, fire is a natural process on the landscape, and has produced extensive areas of longleaf pine (*Pinus palustrus*) forest and wet savannas. These ecological communities support an exceptionally large number of plant and animal species. Historically, much of Louisiana was covered by bottomland deciduous forest with an abundance of ash (*Fraxinus* spp.), elm (*Ulmus* spp.), cottonwood (*Populus deltoides*), sugarberry (*Celtis laevigata*), sweetgum (*Liquidambar styraciflua*), water tupelo (*Nyssa aquatica*), oak (*Quercus* spp.), and baldcypress (*Taxodium distichum*). Most of the upland section is covered with loblolly (*Pinus taeda*) and shortleaf pine (*Pinus echinata*). Much of area has since been converted to agriculture (Neal 1990).

METHODS

Telemetry Data

Black bear radio-telemetry data formed the basis of our model. Bear telemetry data used in this project were collected by Louisiana Department of Wildlife and Fisheries, Louisiana State University, and the University of Tennessee from 1991 to 2012, and included >50,000 individual locations from 20 individual bears. Our telemetry dataset was comprised of very high frequency (VHF) locations (Coastal) and global positioning system (GPS) locations (Tensas, Upper Atchafalaya, and Coastal). Monitoring of coastal Louisiana black bear populations with radio-telemetry began in 1991 (Pace et al. 2000) and generally concluded in 1995 (Wagner 1995); until recently, only sporadic data have been collected on the coastal population (M. McCollister, U.S. Fish and Wildlife Service, personal communication). Currently, there are ongoing studies at the University of Tennessee using GPS technologies to track bears throughout all the subpopulations in Louisiana and we utilized much of those data.

Because of the 2 disparate sources of telemetry locations and the relatively small number of bears monitored, we created standardized rules for the inclusion of the telemetry locations. Telemetry locations were retained for use if an individual bear had $\geq$30 locations within a 2-year period comprised of $\geq$10 of the 12 calendar months. Bears with consecutive weekly locations 5–13 days apart were used to calculate straight-line distances between consecutive points to estimate average weekly minimum movements.

We calculated 75% fixed kernel home ranges for all retained bears. All home range estimates were calculated using the Animal Movement Extension (Hooge and Eichenlaub 1997) in ArcView® GIS (Environmental Systems Research Institute, Redlands, California, USA).

Landscape Data

We used the most recent spatial data available for model development and assumed that the habitat changes that may have occurred since the 1990s did not impact the ability to successfully model current bear habitat use. The land cover data used was the National Land Cover Database 2006 (NLCD 2006). NLCD 2006 is a 16-class land cover classification scheme; that classification scheme is consistent across the United States. NLCD 2006 has a spatial resolution of 30 meters and is primarily based on the unsupervised classification of Landsat Enhanced Thematic Mapper+ (ETM+) circa 2006 satellite data. A formal accuracy assessment of the NLCD 2006 land cover product is still being assessed (Fry et al. 2011). We also obtained 2012 road information from TIGER/Line® data from the redistricting 2010 census (U.S. Bureau of the Census 2010) and rivers and waterbody data from the current National Hydrography Dataset (NHD, U.S. Geological Survey 2009). Our habitat variables were created from land cover, rivers, and roads data with ArcMap® Geographic Information System (GIS; Environmental Systems Research Institute, Redlands, California, USA).

Landscape Metrics

We created 7 variables to describe the habitat of the Louisianan black bear. All the metrics were calculated based on a neighborhood analysis within a circular moving window, the diameter of which was equivalent to the average weekly movement distance of female radiocollared bears (750 m). This window size was used in the original modeling project and seemed to accurately reflect the landscape at a scale relevant to bears (Murrow and Clark 2012).

Land cover- Four variables were created from the NLCD 2006 data. First, we simplified the land cover data by creating a mast-producing forest category comprised of deciduous forest (41 [NLCD classification number]), mixed forest (43), and woody wetlands (90, Table 1). Those cover types have been shown to be important to Louisiana black bears (Nyland 1995, Benson and Chamberlain 2007). The non-forest category represented all other land cover types including urban and barren areas. Using that data layer, we calculated forest density (FOREST) based on a neighborhood analysis of the mast-producing forest category. Then, because there are other "natural" habitats that could be used by bears, we created a percent natural variable (NATURAL) which included all forest (41, 42, 43, 90), grassland (71/72), shrubs (52), and inundated wetlands (95). Finally, using the same NLCD 2006 data, we defined agriculture as pasture/hay (81) and cultivated row crops (82). We then created 2 agriculture variables: percent agriculture (AGRIC) and Euclidean distance to agriculture (DISTAG).

Water- Water density (WATER) was another land cover variable we created. The WATER density variable was calculated based on merging 3 distinct layers: the NLCD 2006 land cover classification "water" (11), a NHD line layer which represented rivers and streams, and a NHD waterbodies layer (USGS 2009). The circular neighborhood analysis was calculated on that merged layer to accurately reflect the density of water cover classes across Louisiana.

Roads- Two road variables were created to address human impacts and fragmentation of the landscape. First we calculated road density (ROADS) based on all roads included in the TIGER/Line® road data. Lastly, we calculated the Euclidean distance to primary and secondary roads (DISTRD) from that same dataset.

Variable Selection- We wanted to reduce the number of variables in the model for simplicity, ease of interpretation, and because some variables may have had poor explanatory power. Therefore, we calculated the mean, coefficient of variation, and range of all 7 variables (Table 3). Variables with high variances within the bear home ranges (i.e., poor explanatory power) or with means that differed little between bear home ranges and the overall study area were considered for elimination.

Analysis

Model Development- There have been a number of developments that make it possible to characterize wildlife habitat needs in a manner that is quantifiable and statistically sound. Multivariate statistical techniques have received increased use in studies of wildlife habitat because univariate statistics often do not adequately describe the many dimensions of habitat usage (James 1971, Shugart 1981, Capen et al. 1986). One such method is based on the Mahalanobis distance statistic (hereafter D^2) which can be applied when only presence data are available (Clark et al. 1993, Alldredge et al. 1998, Tsoar et al. 2007).

D^2 is a multivariate statistic that represents a measure of dissimilarity (Rao 1952) and has been used to assess habitat for a wide range of plant and animal species (e.g., Clark et al. 1993, Knick and Dyer 1997, Corsi et al. 2000, Farber and Kadmon 2003, Buehler et al. 2006, Thompson et al. 2006, Griffin et al. 2010). This technique predicts habitat suitability based on location data and GIS data layers using the following equation:

$$D^2 = (\underline{x} - \underline{\hat{u}})' \textstyle\sum^{-1} (\underline{x} - \underline{\hat{u}}),$$

where $\underline{x}$ is a vector of landscape characteristics in the GIS grid, $\underline{\hat{u}}$ is the mean vector of landscape characteristics estimated from the set of bear home ranges, and $\sum^{-1}$ is the inverse of the variance-covariance matrix calculated from the home ranges (Rao 1952). The D^2 statistic is essentially a dimensionless index of similarity to the multivariate landscape conditions associated with the sampled black bear location data. As an index, units of measure or scaling of model variables are unitless and do not have to be standardized. Small values of D^2 (distances) represent landscape conditions similar to those associated with the bear location data, whereas larger values represent increasingly different conditions. Black bears are good candidates for this habitat modeling approach due to their use of habitats at the landscape scale and the statistic's ability to identify otherwise indistinguishable patterns of landscape use.

Because D^2 scores can range from 0 to infinity, we recoded the D^2 scores to a habitat index ranging in value from 0 to 1,000 using the cumulative frequency distribution (CFD) of all the pixels within all the bear home ranges (Duncan and Dunn 2001). We used 1,000 as the upper limit because it eliminated the need for floating point GIS grids in the Habitat Estimator module we developed based on this analysis (see Appendix A, section 1). Habitat index values closer to 1,000 indicate greater similarity to the landscape conditions defined by the bear home ranges, thus corresponding to more favorable landscape conditions. Because we used the CFD of the bear home ranges to determine the binned values of the reclassification, a habitat index value of 1,000 means that a corresponding pixel is twice as likely to be similar to the habitat target represented by the bear home ranges than a pixel with a habitat index value of 500. It does not mean that that habitat is twice as likely to be selected by a bear as a pixel with a value of 500; that probability is unknown and cannot be estimated with the D^2 method.

Using individual radiolocations as the sampling units (Type III habitat selection, Johnson 1980) may be biased because of unequal sample sizes, telemetry error, and temporal biases in the telemetry data (Kauhala and Tiilikainen 2002, Beier et al. 2003). Also, individual telemetry locations can be spatially or temporally autocorrelated which can produce biases. Such biases have little influence on fixed kernel density home range estimates given adequate sample sizes (Moser and Garton 2007). Therefore, we calculated 75% kernel annual home ranges (Worton 1989) for the animals meeting our inclusion criteria (Fig. 3). We used the 75% home ranges as our sampling units and evaluated their placement on the landscape as our habitat selection criterion (Type II, Johnson 1980). Of the VHF data, only female bears from the 1990s met our inclusion criteria. However, the more recent GPS data included adequate locations for male and female bears. The male bears did not exhibit extremely large home ranges, which would have made them unsuitable for modeling. Because having 2 models would be cumbersome for management applications, we pooled home ranges from males and females for model development.

Model Testing- After constructing the D^2 model, we performed a principal components analysis to determine which variables explained the most variation in the home range data (Morrison et al. 1992). Then, we created 250 potential random home ranges with the same size distribution as the observed bear home ranges (Fig. 4). These random home ranges were created within an evaluation area defined as a 10-km buffer around all 75% kernel home ranges. This prevented arbitrary comparisons of obvious non-bear habitat across Louisiana. Additionally, sections of the random home ranges that primarily fell in a body of water were removed. To quantify bear habitat in the model, we established a cutoff value by determining the point where the cumulative frequency distribution for the original D^2 values associated with the observed and random home ranges had the greatest difference (Browning et al. 2005). We identified the corresponding habitat index values and considered pixels with values above the cutoff to represent suitable bear habitat. We used a Kolmogorov-Smirnov test to indicate differences between cumulative frequency distributions of D^2 values for the observed bear home ranges and the set of random home ranges.

We tested the model with a cross-validation technique to assess model consistency and identify potential outliers or unique home ranges in the data (van Manen et al. 2002). To do so, we recalculated D^2 with all but 1 home range and tested the model with the excluded home range. The model was tested by determining the average D^2 value of the excluded home range and determining whether the mean was above or below the appropriate cutoff value. We repeated that procedure until each home range had been tested once. In each instance, we calculated a new D^2 cutoff score that identified quality bear habitat and calculated the overall proportion of correctly classified home ranges (Verbyla and Litvaitis 1989). Then, for each cross-validation attempt, we identified those home ranges that failed to meet the new threshold. If any 1 home range failed to meet the threshold criterion in $\geq$75% of the trails, it was considered for elimination as an outlier.

Lastly, we determined the predicted D^2 value for each of 116 bear hair sampling sites for another ongoing study in Point Coupee Parrish, LA (Lowe 2011). Those values were compared to 116 randomly generated points within a minimum convex polygon around the original 116 hair sampling sites. The testing methods we chose were robust to extremes in home ranges and sample size (Katnik and Wielgus 2005).

Louisiana Black Bear Habitat Estimator

Based on the final D^2 model, our goal was to develop an estimator and user-friendly interface for recalculating D^2 when landscape changes occur. Examples of such changes are construction of a road, a timber harvest, or bottomland hardwood restoration.

The estimator was designed for ArcMap™ software to evaluate habitat within the state of Louisiana, the primary range of the Louisiana black bear. At this time, the utility does not extend into Arkansas, Mississippi or Texas because of the lack of test data in those locations and the extensive computational requirements of grids encompassing 3 states.

The Louisiana Black Bear Habitat Estimator consisted of 2 main functions: 1) estimation of the cumulative habitat index value within a user-defined polygon and 2) estimation of changes in habitat index value as a result of changes to the landscape (Appendix A). The estimator automates and replicates the GIS processes used to apply the statistical habitat model. That is, the estimator recalculates D^2 and habitat index values based on new pixel and window values but it does not re-parameterize the mean habitat vectors or covariate matrix which were developed from the telemetry data. The estimator is executed from a graphical user interface in the ArcToolbox module of ArcMap™ Version 10.1, and can be operated by users with moderate knowledge of GIS software. We used Python™ scripting language to enable the estimator to be used with ESRI® ArcMap™ software. We chose to use Python™ scripting language, rather than VBScript or Jscript, because it is an open-source compliant, platform-independent programming language with easily readable code.

The Louisiana Black Bear Habitat Estimator was designed to tally the number of bear habitat units within a user-specified polygon before and after simulated land-use changes. Such land-use changes include the conversion of natural land-cover types to non-natural within a polygon (e.g., converting hardwood forest to agriculture) and the addition of roads. Similarly, habitat restoration can be simulated by converting non-natural land-cover types to natural and so forth. The result would be a quantitative estimate of gain or loss in bear habitat units, which is also translated into acres of bear habitat (i.e., acres of land with habitat values >200), as defined by the model. We use acres rather than km^2 in the model output because it is a more familiar unit of measure to most land managers. Therefore, we will report acres in the simulation examples.

To simulate the effects of a potential land-use change, the user provides a polygon (any shape or size) of the proposed evaluation site as an ArcMap™ shapefile. In general, the user has 3 main options of what happens to the entire area: 1) land cover within the polygon changes to "natural" and becomes deciduous, mixed, or wetland forest; 2) land cover within the polygon changes to "natural" and becomes herbaceous, shrub, or evergreen forest; 3) land cover within the polygon changes to "non-natural". The user also has the option to add roads. Once the data are entered, the model recalculates all impacted data layers. The estimator then recalculates the habitat grid using the original multipliers derived from the Mahalanobis distance calculation. The resulting map layer delineates habitat change within the user-defined polygon and a 1,500-m buffer (see Appendix A). Finally, an Excel file is created that specifies the quantitative change in bear habitat units within the area of the input polygon, reflecting a loss or gain in bear habitat.

RESULTS

The complete telemetry dataset consisted of >50,000 locations representing 76 individuals over 19 years (1993–2012). We reduced that to dataset to 20 (7M:13F) individuals after we applied our criteria for inclusion. Three home ranges were subsequently removed during initial model calibration after being identified as significant outliers (failed to meet the threshold criteria in $\geq$75% of trials), reducing the number of home ranges used to 17 (7M:10F). Two of these home ranges had high percentages of non-natural land cover (>70%) and one had high water and road values (11% and 4%, respectively). Upon further investigation, the non-natural area in at least one home range was actually a hunting camp that was succeeding into forest but was classified as urban in the NLCD 2006 layer.

The 75% home ranges for the 10 females averaged 6.91 km^2 (SE = 2.35), ranging from 1.18 to 20.36 km^2 and 16.88 km^2 (SE = 6.34) for the 7 males ranged from 1.86 to 47.19 km^2. Mean weekly movements were 3,532 m (*n* = 7, SE = 576.47) for males and 1,578 m (*n* = 10, SE = 200.64) for females. The 75% kernel home ranges (n = 17) and the 192 randomly generated home ranges used in model building and testing covered 187.23 km^2 and 2,029 km^2, respectively (Figs. 3 and 4). The evaluation area used for variable and model testing was 2,449 km^2.

Of the 7 variables we considered, 4 were used in the final model (Tables 2 and 3). The 3 excluded variables all had high variability based on 1 standard deviation and in all cases the relationship did not make biological sense. Bear home ranges tended to be relatively close to agriculture and encompass areas with a small to moderate amount of agriculture. They also tended to be close to roads. When those variables were included, the model became highly biased against areas far from agriculture and roads. For example, Tensas River National Wildlife Refuge was identified as poor bear habitat because of low levels of agriculture and slightly higher distance to main roads. The principal components analysis indicated that the first 2 eigenvalues of the correlation matrix explained 90% of the variation while the first 3 explained 98%. Each retained variable exhibited a strong relationship with at least 1 principal component (Table 4).

The principal components analysis indicated the first 2 components each explained >10% of the model variation and both exceeded the broken-stick eigenvalues (Table 5). The model variable with the strongest correlation in the first principal component was NATURAL. That variable was the most indicative of where general bear habitat was located (Table 5). The second component seemed to reflect the overall nature of bear habitat when described by those 4 variables. The signs of the components reflect the nature of the relationship to the other variables within that same component. ROADS and WATER were positively correlated with each other while FOREST and NATURAL were negatively correlated. In the second component, FOREST outweighs NATURAL and its presence is a stronger driver of quality bear habitat.

The average D^2 value for Louisiana was 698.30 (SD = 1,860.39) and the evaluation area had a D^2 value of 341.07 (SD = 1,247.32). The average D^2 values across individual bear home ranges ranged from 7.90 to 29.23 ($\bar{x}$ = 17.06, SE = 1.47; Table 4). The random sample of home ranges (n = 192) generated within the evaluation area had average D^2 values ranging from 5.01 to 7,347.24 ($\bar{x}$ = 272.86, SE = 58.30). Those random home ranges differed from the observed bear home ranges as supported by the Kolmogorov-Smirnov test (D = 0.46, P < 0.01). The largest separation between the 2 cumulative frequency distributions occurred at a D^2 value of 30, with 100% of the bear home ranges falling below that cutoff (Fig. 5). The threshold 30 corresponded to a habitat index value of 200. From the 116 hair-sampling stations where bears were documented, 96 (83%) were located in pixels with D^2 values less than our cutoff, with a mean of 19.33 (SE = 1.87) ranging from 2.63 to 135.09. A random sample of 116 locations generated around the hair-sampling stations had an average D^2 value of 102.05 (SE = 14.14), and the Wilcoxon rank-sum test confirmed that those locations came from a different distribution than the hair sampling locations (W = 17,399.5, $P < 0.01$). Cross-validation of the final model resulted in 94% (16 of 17) of the home ranges being correctly classified.

Once reclassified, the highest habitat index values occurred within current black bear range, whereas the lowest values occurred in highly urbanized areas such as the city of New Orleans (Figs. 6 and 7). In general, high habitat index values occurred in areas with low to moderate road density, high forest density, and a high percentage of natural cover types.

LOUISIANA BLACK BEAR HABITAT ESTIMATOR

We evaluated the performance of the estimator to assess landscape changes by simulating 2 hypothetical land cover alterations located in the central and then the northern portion of bear range in Louisiana (Figs. 8 and 9). The first simulation was a land use change allowing an agricultural field to revert to natural cover (Figs. 8A and 8B). Then, we simulated that that same field was "planted" in bottomland hardwood trees species (becoming natural-forest, Fig. 8C). The original polygon with a buffer of

500 m had 560 acres (2.3 km^2) of bear habitat (index value >200). When converted to natural non-forested cover, that same area had 731 acres (3.0 km^2) of quality bear habitat (an increase of 171 acres). Lastly, when the polygon was converted to bottomland hardwoods, the total acreage of bear habitat increased to 3,363 acres (13.6 km^2).

The last simulation (Figs. 9A and 9B) was a deforestation and conversion to agriculture with a small development on a private inholding within the boundaries of Tensas River National Wildlife Refuge. There was 6,769 acres of bear habitat within the land parcel (1,466 acres (5.9 km^2)) plus a 1,500-m buffer (7,365 acres (29.8 km^2); Fig. 9A). Fig. (9B) shows a simulation of the potential change in habitat values for that parcel if converted to agriculture with a small housing development (new roads). After the simulation, the polygon plus buffer has only 5,722 acres of bear habitat, a loss of 1,047 acres primarily from within the polygon.

DISCUSSION

Compared with an earlier model developed to identify potential impacts of hurricane Katrina and Rita, the current model is on a much larger scale and is slightly simplified to accommodate that expanse and the varying habitat conditions across Louisiana (Murrow and Clark 2012). Interestingly, it seems to perform as well if not better than the previous model and the spatial pattern of habitat index values for the original coastal study area was similar for both models. After several outlier home ranges were removed, all tests indicated model predictions were reliable and identified several habitat variables that were strongly correlated with bear habitat quality. Areas with a high percentage of natural cover (forests, grasslands, shrublands, cypress swamps), low road density, limited water, and with higher mixed, deciduous, and woody wetland forests were indicative of quality bear habitat. This is consistent with studies on bear habitat use in Louisiana (Nyland 1995, Wagner 1995, Pace et al. 2003, Wagner 2003, Benson and Chamberlain 2007). As with the coastal model (Murrow and Clark 2012), the statewide model identified Weeks Island as higher quality habitat except in the small sections of highly industrialized area, and it identified areas of high quality bear habitat along the boundary of Assumption and Terrebonne parishes. Again, when we tested our model in Point Coupee Parish with independent data, our model was very successful at identifying bear habitat.

Data availability and quality are considered the primary limiting factors of GIS-based models (Corsi et al. 2000). The effect of potential misclassification errors in our spatial data was reduced because landscape measures were averaged within a larger window (1.8 km^2) rather than values of individual pixels (Didier and Porter 1999). Additionally, reclassification of land-cover data into more general categories further reduced effects of misclassification error. Thus, the habitat model likely was not sensitive to error associated with bear locations or GIS source data.

To test the model and for use in the GIS utility, it was necessary to use a cutoff value to discriminate between habitat and non-habitat. However, the D^2 values in our model represent a continuum and an absolute threshold value is an oversimplification. Values higher or lower than the value we chose may be more appropriate depending on the management objectives and associated risks. The choices we made for defining or pooling variable categories can affect the model outputs but, ultimately, the model target is based on the bear home ranges. Meaningful predictions, as evidenced by mean habitat index values of observed and random home ranges, would not have resulted if those variable choices were not relevant to the animals under study.

There are some limitations to using a GIS-based tool to simulate habitat change. Our model is based on the assumption that the bear home ranges are distributed optimally within the landscape and the bears we chose for analysis were typical of the overall bear population. The telemetry data from 2001 to 2005 were collected slightly earlier than several of the GIS data sources (NLCD: 2006; NHD; 2009; Tiger: 2010). We recognize that some land-use changes may have occurred that were not incorporated into the telemetry data but we assume that species-habitat relationships have not dramatically changed over this short time frame. We also recognize the inability of the NLCD to capture some of the Wetland Reserve Program (WRP) and Conservation Reserve Program (CRP) land use changes and the inputs could potentially be updated at a later point in time without having to recalibrate the model. Also, we recognize that forest land cover in some portions of the state (particularly the lower Atchafalaya River Basin) may be classified as woody wetland (90) in the NLCD but may be semi-permanently flooded and not suitable bear habitat. Managers should be aware of this and evaluate model predictions appropriately. As time elapses and new spatial data become available (e.g., 2020 U.S. Census Bureau roads), the landscape variables used to develop the habitat model can be updated. The statistical model (i.e., mean vectors and covariance matrices) should not have to be re-parameterized unless the landscape within the study area dramatically changes.

Simulation models allow managers and stakeholders involved in landscape planning to compare the outcomes of diverse scenarios. Simulation tools are commonly used in risk-benefit analyses and to inform policy-making decisions. Our simulation tool provides a comprehensive comparison of habitat management alternatives by simultaneously incorporating several factors and their interactions that influence bear habitat suitability. That is, habitat units can be totaled and directly compared among different land management alternatives regardless of any specific threshold and the amount of "suitable" bear habitat gained or lost can be determined. This provides more realistic predictions of habitat change than could be produced by evaluating changes in a single variable, such as land use or road density. Additionally, the estimator quantifies not only how land-use changes could affect the land parcel, but how such changes could affect the surrounding area beyond the boundaries of the parcel. Users should be aware that the percent loss or gain in habitat units as a result of a land use change may not be directly proportional to the impact of that activity on bear population fitness. Nevertheless, we view these metrics as useful tools for quantifying land use changes from a biologically relevant standpoint.

The Bear Habitat Estimator automates the process of parameterizing the bear habitat model, providing both visual (Fig. 7) and quantitative output (Fig. 8) that allows the user to evaluate the effect of land use changes before they occur (Appendix A). The estimator can be used by persons with moderate GIS skills and basic knowledge of the analysis techniques and bear habitat requirements to conduct simulations of habitat degradation or restoration. We note that the estimator is applying the same statistical model originally developed with the bear radiotelemetry data, but with the user specifying changes in the pixel values of the landscape variables to reflect potential landscape alterations. Thus, the radiotelemetry data do not have to be updated.

To conduct a realistic simulation of the effects of typical bear habitat alterations, it was important to simultaneously consider different sources of impact. For example, a housing development would have a much greater impact on bear habitat compared with agricultural land use only because of the low tolerance, and our results reflect this via the roads variable.

The habitat model we used as the basis for this habitat estimator is specific to the state of Louisiana. Because the programming code that underlies this habitat estimator can be easily modified, it could be adapted to any species for which suitable presence information is available to facilitate an objective, transparent process for evaluating habitat. Reliable location data and relevant landscape data at an appropriate scale are key requirements for developing habitat models for the species of interest. As with all models, our model is only as good as the data upon which it is based. There is no substitute for on-the-ground evaluations and we strongly suggest that our modeling projections should be verified on site. For example, visits by field biologists or sign surveys at sites ranked as having low-, medium-, or high-quality bear habitat can serve as further model support and validation.

MANAGEMENT IMPLICATIONS

The model clearly depicted the limited and fragmented nature of bear habitat in Louisiana. Coastal black bears are isolated from bear populations in the upper Atchafalaya by several highways and flooding in the Atchafalaya basin. Consequently, land acquisition has been an important conservation measure for Louisiana black bear recovery (U.S. Fish and Wildlife Service 1995). Enhancement or the creation of movement corridors could help improve black bear habitat throughout Louisiana (Pelton 1982, Lande 1987, Noss 1987, Anderson 1997) and our model identifies habitat throughout and between the disjunct populations (Fig. 6).

As with all models, we view ours as an aid to, rather than as a substitute for, sound decision making. We strongly recommend that our GIS analysis should be verified with field surveys before management actions are taken.

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LITERATURE CITED

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Table 1. Land-cover type groupings used for the model of occupied bear habitat calculated in Louisiana, 1993–2012.

NLCD 2006 land cover type (classification number)	Natural (1) /Non-natural	Forest
High developed (24)	0	0
Medium developed (33)	0	0
Low developed (22)	0	0
Developed open space (21)	0	0
Cultivated/row crops (82)	0	0
Pasture/hay (81)	0	0
Grasslands (71/72)	1	0
Deciduous forest (41)	1	1
Evergreen forest (42)	1	0
Mixed forest (43)	1	1
Scrub/shrub (52)	1	0
Woody Wetland (90)	1	1
Emergent Herbaceous Wetland (95)	1	0

Table 2. Descriptions of landscape-scale variables, calculated with a 750-m radius circular moving window, considered for inclusion in the bear habitat model for Louisiana, 1993–2012.

Variable name	Variable description	Variable units and range
FOREST*	Percent forest including deciduous, mixed, and palustrine forest types	% and $0 \le$ FOREST ≤ 1
NATURAL*	Percent of natural land cover types	% and $0 \le$ ROADS ≤ 1
WATER*	Percent Water	% and $0 \le$ WATER ≤ 1
AGRIC	Percent of agriculture	% and $0 <$ AGDEN ≤ 100
DISTAG	Distance to nearest agriculture	m and $0 <$ DISTAG ≤ 50000
ROADS*	Road density	% and $0 \le$ ROADS ≤ 1
DISTRD	Distance to nearest primary or secondary road	m and $0 <$ DISTRDS ≤ 50000

*Denotes variables retained in the final model

Table 3. Mean ($\bar{x}$), standard error (SE), range, standard deviation (SD) of landscape-scale variables associated with bear home ranges, evaluation area, and statewide included in the bear habitat model for Louisiana, 1993–2012.

	Bear home ranges			Evaluation area		Louisiana	
Variable	$\bar{x}$	SE (n = 17)	Range	$\bar{x}$	SD (n = 1)	$\bar{x}$	SD (n = 1)
FOREST	0.78	0.03	0.58–0.97	0.41	0.36	0.26	0.29
NATURAL	0.89	0.02	0.77–0.99	0.49	0.38	0.61	0.37
WATER	0.06	0.00	0.03–0.09	0.10	0.17	0.14	0.25
ROADS	0.02	0.01	1.43–7.21	0.03	0.04	0.04	0.05
AGRIC	0.11	0.04	0.00–0.64	0.41	0.36	0.21	0.32
DISTAG	1,014.38	153.26	29.90–2,302.94	736.39	1,318.02	2,244.53	4,400.68
DISTRD	2,298.04	274.00	386.01–3,878.15	2,049.66	1,849.15	19,610.29	32,150.17

Table 4. Principal component loading vectors of metrics calculated for Mahalanobis Distance model of bear habitat model in Louisiana, 1993–2012.

	Component loading vectors			
Variable	1	2	3	4
ROADS	0.20	0.82	0.54	0.06
FOREST	0.54	-0.44	0.39	0.60
WATER	0.53	0.34	-0.74	0.25
NATURAL	0.62	-0.17	0.11	-0.75

Table 5. Eigenvalues and proportion of variance explained by 4 principal components for the correlation matrix of a Mahalanobis distance model to evaluate Louisiana Black Bear habitat within Louisiana, 1993–2012.

Principal component vector	Eigenvalue	Proportion of variance	Broken-stick model proportion of variance*
1	2.4069	0.6017	0.5208
2	1.2089	0.3022	0.2708
3	0.3399	0.0850	0.1458
4	0.0442	0.0111	0.0625

*Proportions for any 4 variable model (see Frontier 1976 and Jackson 1993)

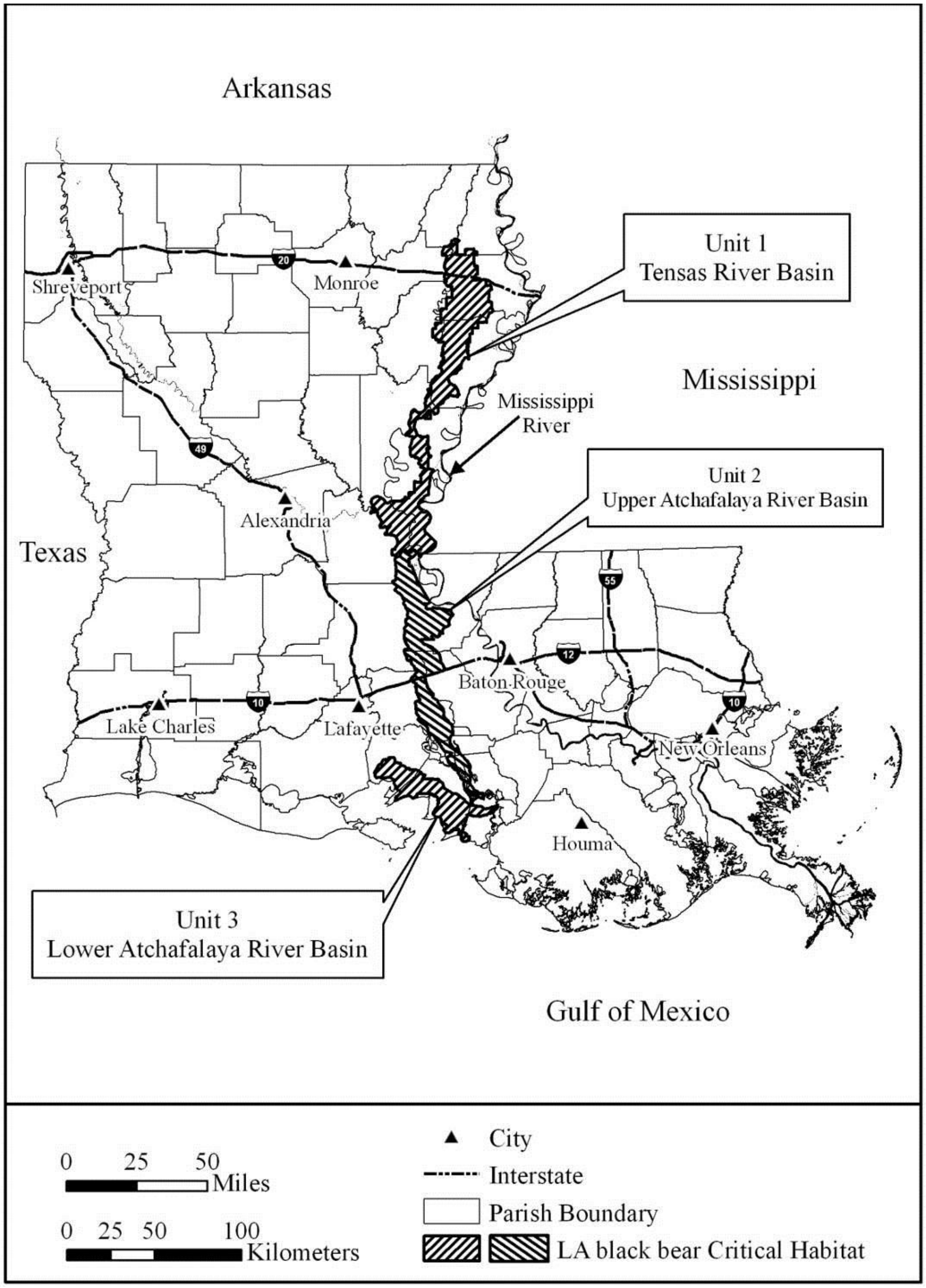


Figure 1. Designated critical habitat for black bears in Louisiana. (Source: USFWS [http://www.fws.gov/southeast/news/2008/r08-021.html]), 2008.

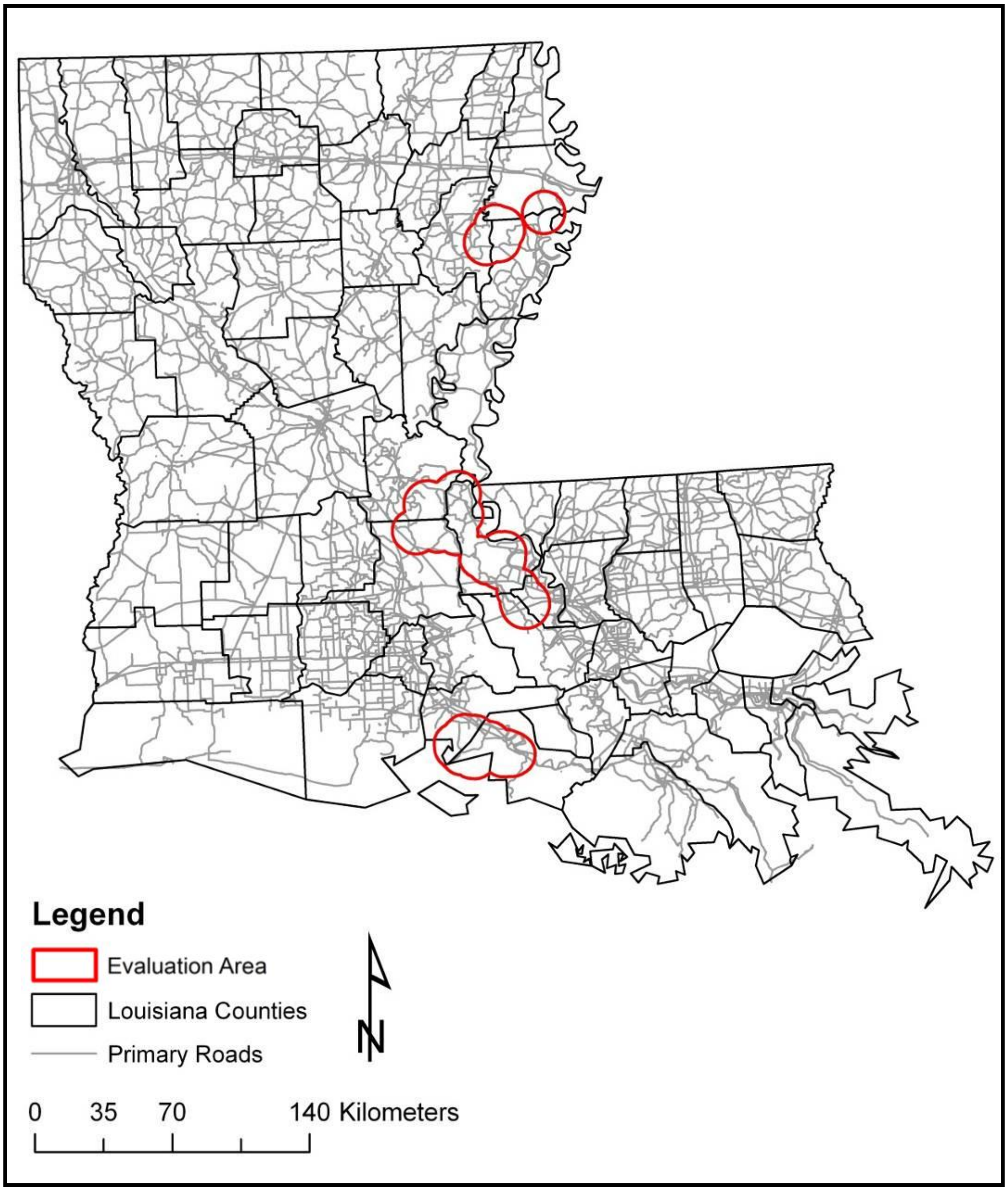


Figure 2. Evaluation area used for testing performance of a black bear habitat model for Louisiana, 1993–2012.

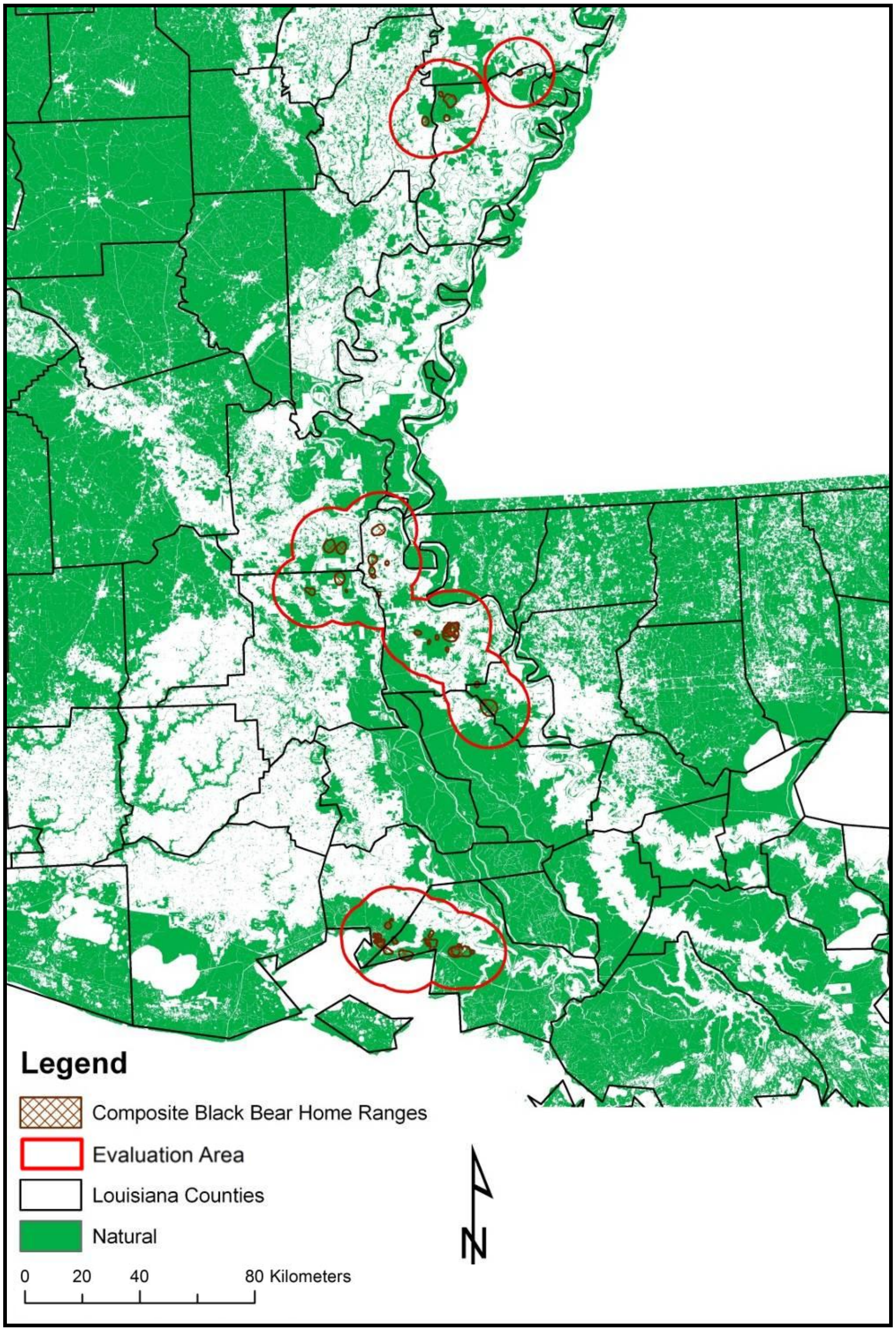


Figure 3. Twenty black bear home ranges eligible for consideration in the black bear habitat model for Louisiana overlaid on natural land cover types, 1993–2012.

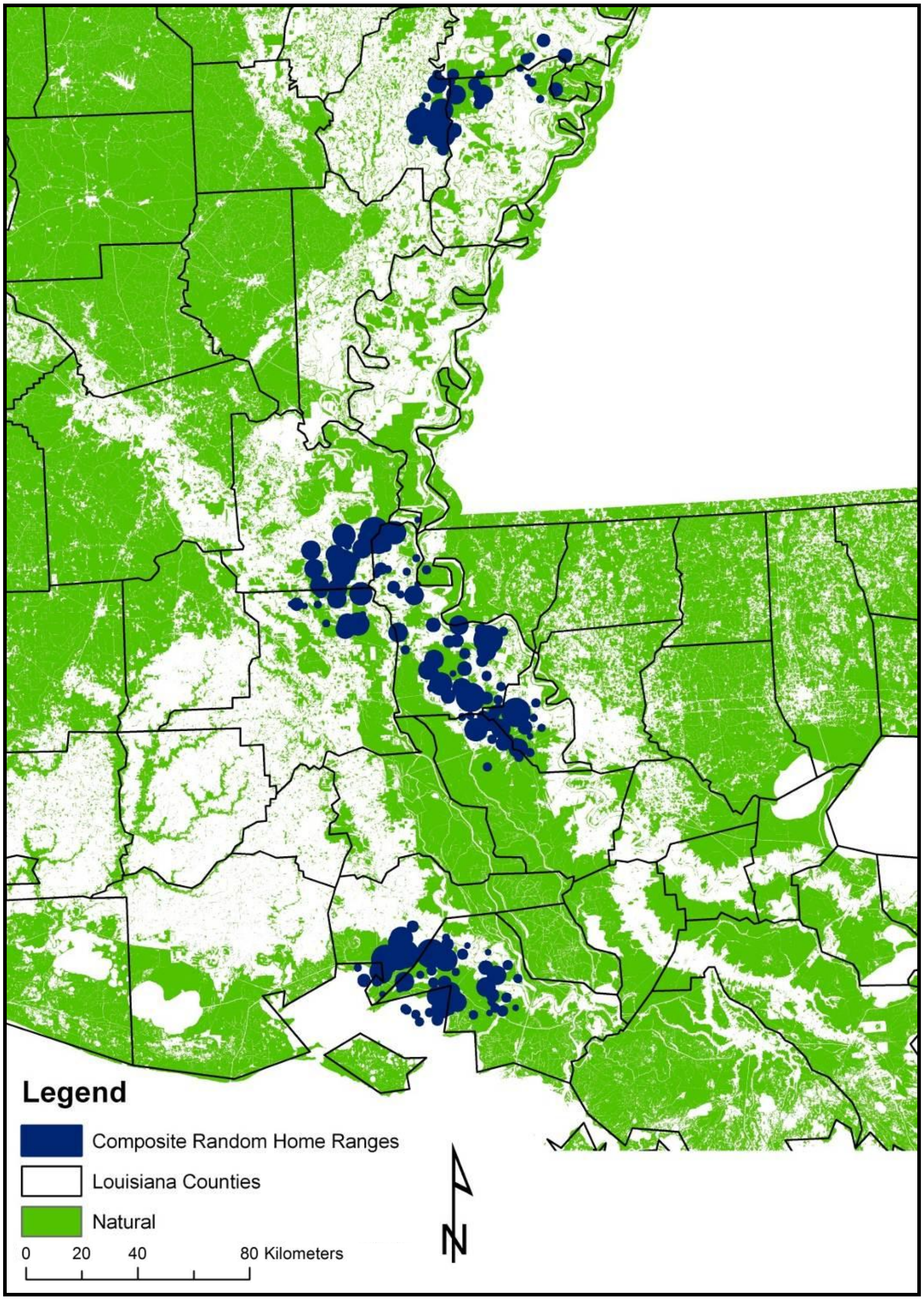


Figure 4. Random home ranges eligible for consideration in the black bear habitat model for Louisiana overlaid on natural land cover types, 1993–2012.

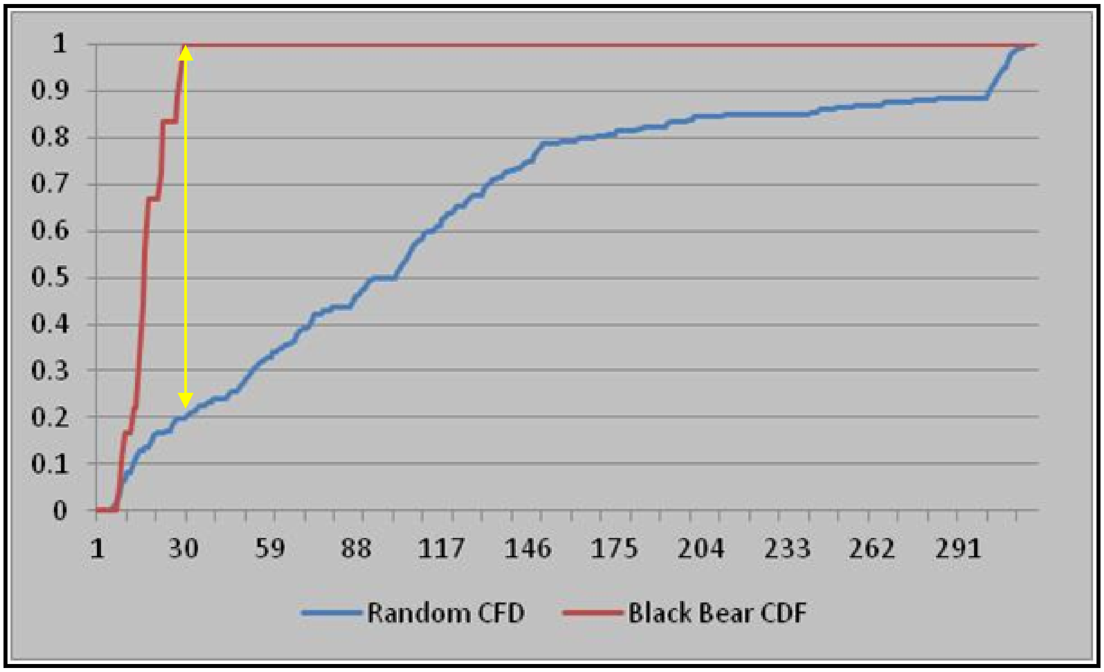


Figure 5. Cumulative frequency (Y-axis) distributions of observed black bear home ranges (red) and random home ranges (blue) by average Mahalanobis distance statistic value (X-axis). The yellow line marks the largest separation between the 2 distributions (30).

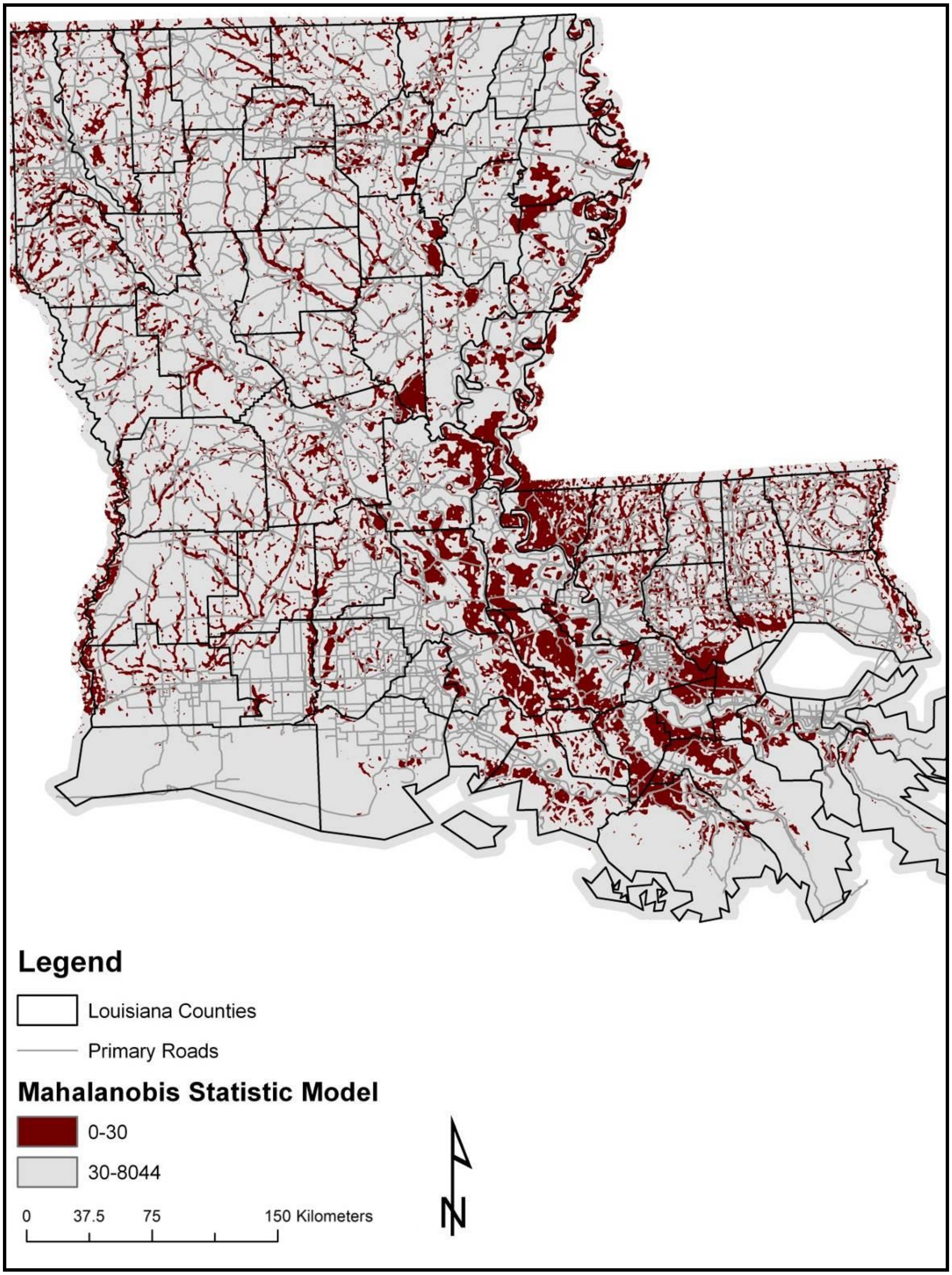


Figure 6. Mahalanobis Distance statistic model Louisiana with a threshold of <30 defining "quality" bear habitat.

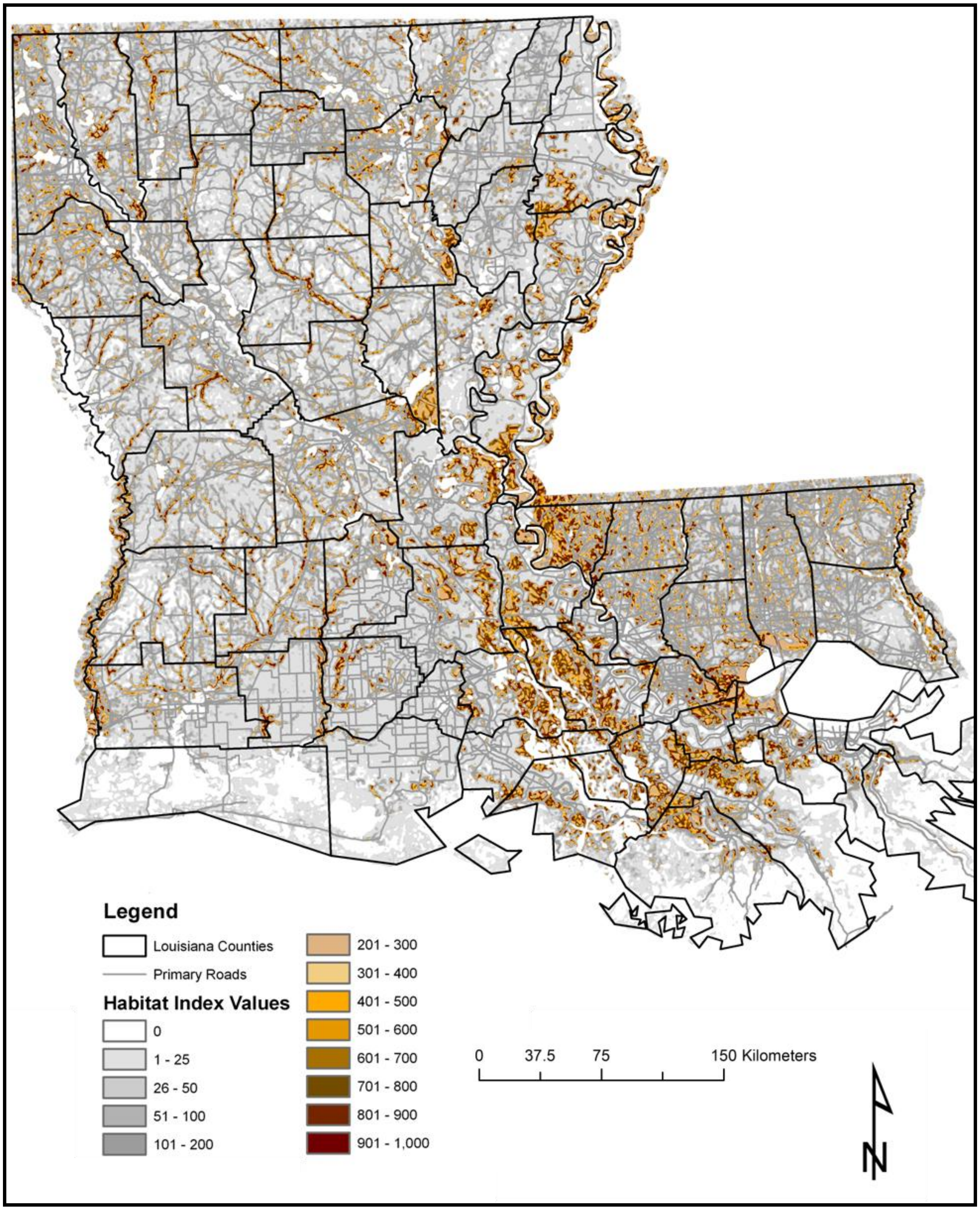


Figure 7. Habitat index values (reclassified Mahalanobis distance statistic model based on CDF of bear home ranges) for Louisiana. Values >200 are considered "quality" bear habitat with values closer to 1,000 representing better bear habitat.

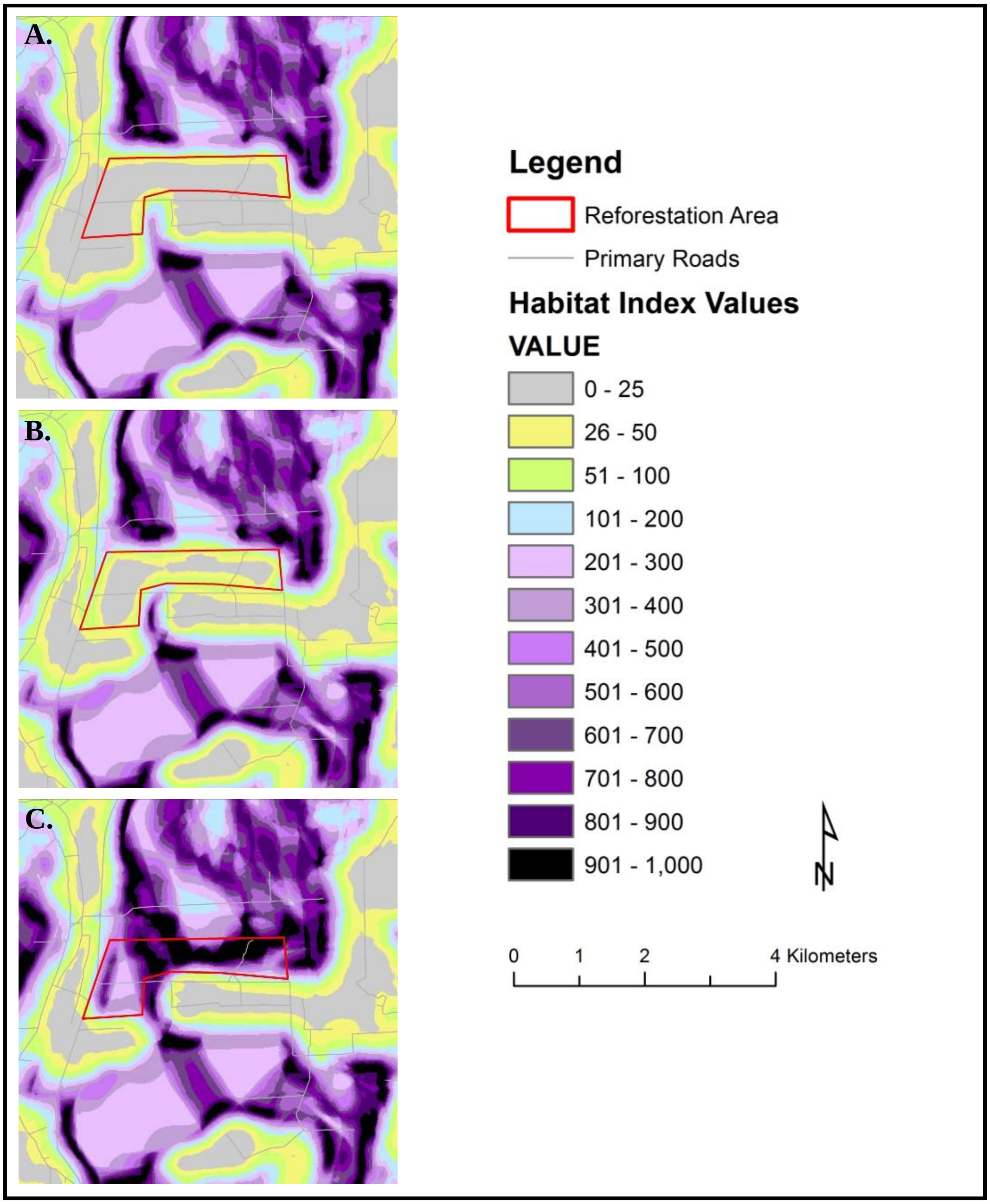


Figure 8. Map output from the Habitat Estimator to quantify the impact of land use changes on bear habitat (Index value > 200) in Louisiana. Prior to land use change, 560 acres of bear habitat occur within the red boundary line and a 500-m buffer (Fig. A). Fig. (B) shows a simulation of the change because of conversion to natural land cover (731 acres of bear habitat within the polygon and buffer). Fig. (C) shows a simulation of the conversion to forest land cover (3,363 acres of bear habitat within the polygon and buffer).

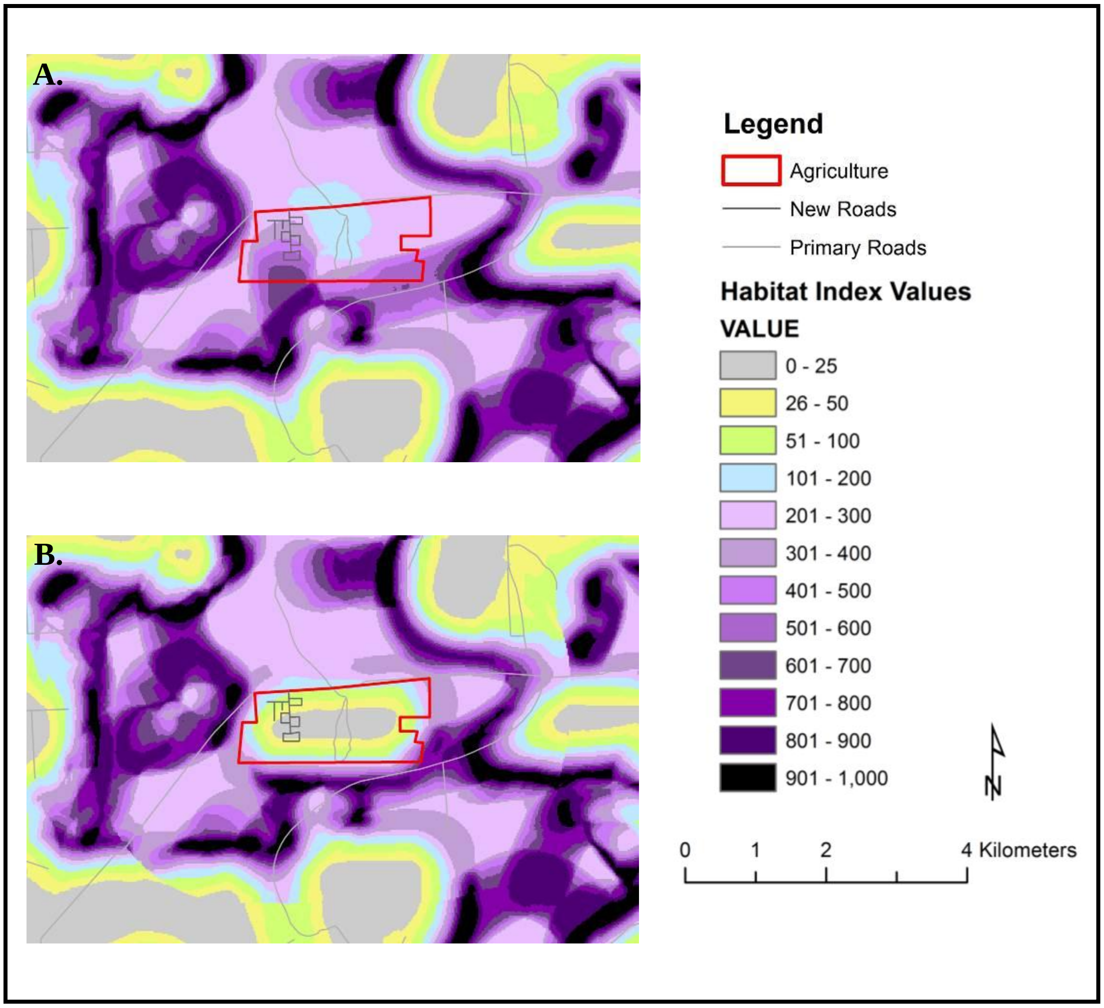
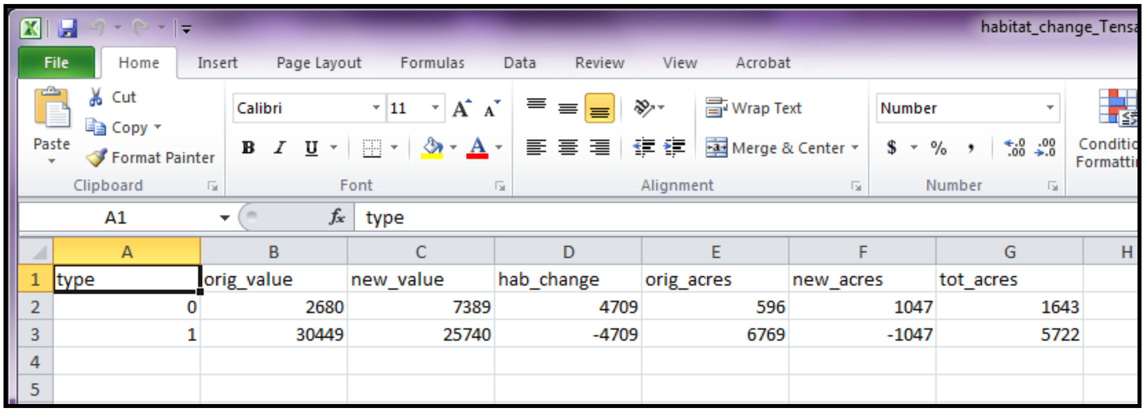


Figure 9. Map output from the Habitat Estimator to quantify the impact of land use changes on Tensas River National Wildlife Refuge, Louisiana. Prior to land use change, 6,769 acres of bear habitat occur within the polygon plus a 1,500-m buffer (A). Fig. (B) shows a simulation of the potential change in habitat values for that parcel if converted to agriculture with a small housing development (new roads). After the simulation, the polygon plus buffer has only 5,722 acres of bear habitat, a loss of 1,047 acres primarily from within the polygon



	A	B	C	D	E	F	G
1	type	orig_value	new_value	hab_change	orig_acres	new_acres	tot_acres
2	0	2680	7389	4709	596	1047	1643
3	1	30449	25740	-4709	6769	-1047	5722

Figure 10. Excel output from the Habitat Estimator to quantify the impact of hypothetical land use changes on Tensas River National Wildlife Refuge, Louisiana (See Fig. 9).

APPENDIX A: LOUISIANA BLACK BEAR HABITAT ESTIMATOR: USER'S MANUAL

Louisiana Black Bear Habitat Estimator

User's Manual

Contents

University of Tennessee
Department of Forestry, Wildlife and Fisheries

U.S. Geological Survey
Leetown Science Center
Southern Appalachian Research Branch

Information

Title: Louisiana Black Bear Habitat Estimator
Authors: Jennifer L. Murrow, Steve Flanagan, Cindy A. Thatcher, Joseph D. Clark
Organizations: University of Tennessee and U.S. Geological Survey's Southern Appalachian Research Branch.
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Version: 1.0 for ArcGIS/ArcMap™ 10.1

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1. INTRODUCTION

The **Louisiana Black Bear Habitat Estimator** was designed for ArcGIS/ArcMap™ (ESRI®, Redlands, California, USA) geographic information system (GIS) software version 10.1 to evaluate Louisiana Black Bear Habitat. The **Louisiana Black Bear Habitat Estimator** is a simulation tool that calculates how the value of Louisiana Black Bear habitat would change due to habitat alterations within a user-defined polygon and the surrounding area. The value of bear habitat is based on a statistical model (see Murrow and Clark 2012, Murrow et al. 2013). Higher values correspond with higher quality Louisiana Black Bear habitat and the change in habitat values can be summed to estimate the loss of habitat caused by development, habitat restoration, or other habitat alterations. The **Estimator** can also be used to calculate the current value of bear habitat for any user-defined polygon.

Background

Home ranges of 17 individual bears were used to develop a statistical habitat model. These home ranges were calculated from Louisiana Black Bear telemetry data collected from 1995–2012. The landscape variables in the habitat model include paved road density, percent forest, percent natural land cover, and percent water (Table 1). All variables were calculated using neighborhood analyses in ArcMap™ GIS software. The mean landscape conditions of those variables within bear home ranges formed the target to which the remainder of the site was compared. Mahalanobis distance, a multivariate statistic that represents a measure of dissimilarity, was used as the primary habitat modeling technique (Clark et al. 1993). Mahalanobis distance was calculated for each pixel in the study area using ArcMap™ GIS. The values represent a quantitative index of bear habitat use.

Mahalanobis distance values were recoded to habitat index values based on the cumulative frequency distribution of the model results within bear home ranges. Recoding to values of 0–1,000 was applied to the habitat index values to avoid the need for a decimal (floating point) GIS grid. Values closer to 1,000 indicate a greater similarity to the landscape conditions defined by the bear home ranges. Thus, greater habitat index values correspond to more favorable landscape conditions for the Louisiana black bear. Technical details regarding the application of statistical techniques to assess Louisiana Black Bear habitat are provided by Thatcher et al. (2006*a,b*; 2008), Murrow and Clark (2012), Murrow et al. 2012, and Murrow et al. 2013.

The **Habitat Estimator** can be used to determine the current bear habitat value of any land parcel. The **Habitat Estimator** can also be used to estimate the change in habitat index values due to simulated habitat alterations. The latter is accomplished by recalculating the statistical habitat model based on updated landscape conditions provided by the user. To perform this operation, the user provides a polygon of the site that is proposed for habitat alteration as an ArcMap™ shapefile (projection = Albers NAD 83), which is then used to recalculate the implicated model variables. The user can add new roads associated with the habitat alteration to the existing roads GIS layer, and road density is recalculated. Finally, the user has the option to customize the size of the analysis area by indicating a buffer distance beyond the polygon boundaries. The analysis area should be large enough so that all changes in habitat value are accounted for, but excluding distant, unaffected areas to reduce computing time. The percent water variable is held constant. The **Estimator** creates an Excel file that specifies the quantitative change in bear habitat units and habitat acres. The output also includes an ArcMap™ grid that provides a visual representation of the user-specified landscape changes in terms of bear habitat value.

For example, perhaps a user is interested in the impacts of a small housing development. The user could change the land parcel shapefile from forest to urban cover and add a road shapefile depicting the layout of the community. The utility would then recalculate the value of that land and the surrounding buffer area.

Table A-1. Data sources for habitat model to evaluate Louisiana Black Bear habitat within the study area.

Data source	**Year**	**Agency**
TIGER/Line® data from the redistricting 2010 census	2010	U.S. Bureau of the Census 2010
National Hydrography Dataset	2009	U.S. Geological Survey 2009
National Land Cover Database 2006	2006	MRLC Consortium and U.S. Geological Survey
Louisiana Black Bear telemetry data	1995–2012	Louisiana Fish and Wildlife Conservation Commission, LSU, UTK, USFWS

Literature Cited

Clark, J. D., E. Dunn, and K. G. Smith. 1993. A multivariate model of female black bear habitat use for a geographic information system. Journal of Wildlife Management 57:519–526.

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Murrow, J. L., S. Flanagan, C. A. Thatcher, F. T. van Manen, and J. D. Clark. 2013. Louisiana Black Bear Habitat Estimator for ArcMap™ (version 1.0). U.S. Geological Survey, Leetown Science Center, Southern Appalachian Research Branch, Knoxville, Tennessee, USA.

Murrow, J. L., Thatcher, C. A., van Manen, F. T. and J. D. Clark. 2012. A Data-Based Conservation Planning Tool for Florida Panthers. Environmental Modeling and Assessment 18:159–170.

Thatcher, C. A., F. T. van Manen, and J. D. Clark. 2006*a*. Identifying suitable sites for Florida panther reintroduction. Journal of Wildlife Management 70:752–763.

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Thatcher, C. A., F. T. van Manen, and J. D. Clark. 2008. Estimating effects of land-use changes on Florida panther habitat. Final report. U.S. Geological Survey, Leetown Science Center, Southern Appalachian Research Branch, Knoxville, Tennessee, USA. 30pp.

2. DATA PREPARATIONS AND STARTING THE ESTIMATOR

NOTE: The input shapefiles must be in the following projection:
Albers_North American Datum 1983 (NAD_1983_Albers).

Determine if you have ArcMap™ 10.1:

In ArcMap™, click on Help, and choose "About ArcMap™". Because of significant differences between the versions of ArcMap™, this estimator is only compatible with version 10.1. You will need the full ArcInfo license (rather than the lesser ArcView license) and the spatial analyst extension, which should be turned on.

Copy program files and data from CD:

It is suggested to run the utility from the provided flash drive or to copy the entire folder labeled "bear_habitat_estimator" to your hard drive. Because this folder contains many grids, you must use ArcCatalog to copy and paste the folder. Copying and pasting the folder or grids using your standard Windows Explorer file view will corrupt the grids. Once you have copied the folder via ArcCatalog, open the folder with Windows Explorer to check that all files were moved. Then, view the grids in ArcCatalog by opening ArcCatalog, selecting any grid in your folder and selecting the preview tab. You are typically asked to build pyriamids. Select "No" and the grid should properly appear in the preview window. This is the most common cause for errors in the running of the utility. The working directory folder will be from wherever you choose to run the Utility.

Prepare input data:

You will need an ArcMap™ polygon shapefile representing the boundaries of the area of interest. Optionally, you can specify additional roads.

Input polygon: This is a polygon shapefile representing the boundaries of the land parcel that is being considered for summary or alteration. The shapefile must contain only a single polygon. Copy the polygon file to your working directory.

Input roads (optional): This is a polyline shapefile representing any additional roads associated with land use changes within the polygon. Copy the polyline shapefile to your working directory.

Study area size (optional): The Louisiana Black Bear Habitat Estimator provides the option of specifying the size of the study area (area to which the analysis will be confined). The standard buffer distance used by the estimator is 1,500 m (the mean bear home-range radius) beyond the boundaries of the input polygon. Limiting the analysis area greatly decreases computing time. Do not choose a buffer distance <750 m because that is the distance needed to recalculate the variables in the model.

Other Important preparations and running processes:

Prior to any new run, ALWAYS Delete, move, or rename any previous output (i.e., the *FINALRESULT* grid, the scratchWS folder, *habitat_change_summary.xls and habitat_change_summary.dbf*) before launching the toolbox. When deleting grids or folders containing grids, always use ArcCatalog™ rather than Windows Explorer to avoid corrupting the info files associated with each grid.

Do not delete the *Final Results.lyr* file from your working directory (it controls the display of the *FINALRESULT* grid).

Finally, **close and restart ArcMap™ each time you run a simulation** to ensure that temporary files and schema locks from previous simulations have been removed.

You must ascertain the file path of your **ArcGis Toolboxes** and make sure that this Utility specifies the correct path for your computer. Typically, the ArcGis Toolboxes are located at (C:\Program Files\ArcGIS\Desktop10.1\ArcToolbox\Toolboxes). If that is the location on your computer, the script will run with no problems. If you have another location or a (86x) in the pathname, the script will have to be modified before the Utility can be run. This is easily done by right-clicking on the hab_estimator.py file in Windows Explorer and opening the file in NOTEPAD. Then scroll to the section at the beginning of the code labeled # Load Required Toolboxes (see below). Change the path names and select FILE-SAVE. If this is necessary, you may need to re-import the new script. Right click on the script icon in the ArcToolbox and select import script. Navigate to the newly modified file and select OK.

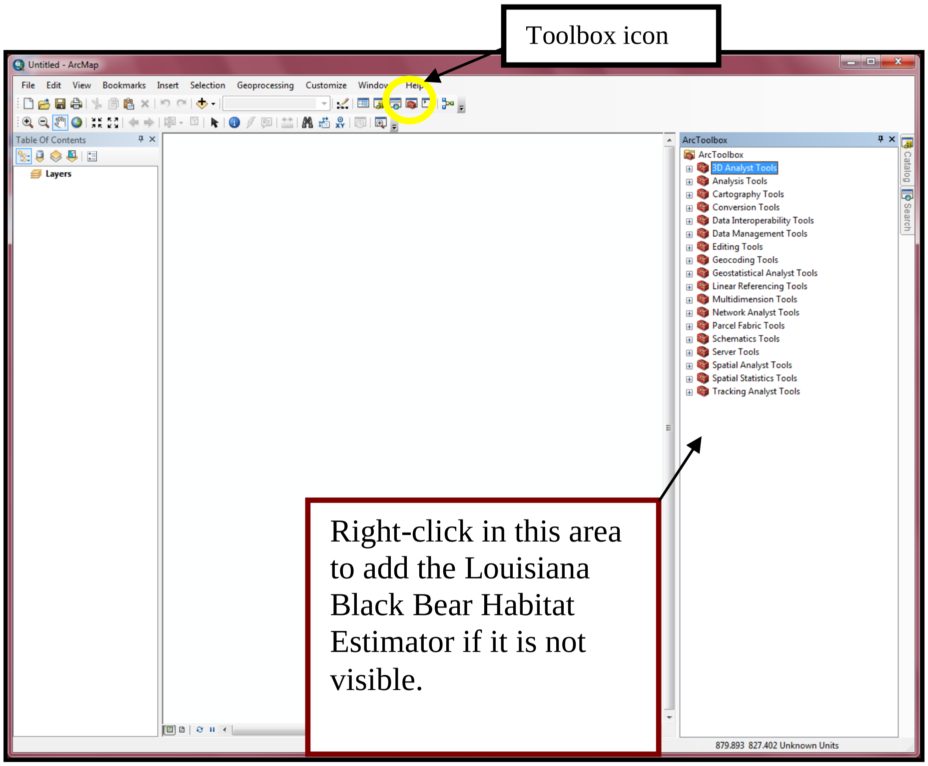
hab_estimator - Notepad

File Edit Format View Help

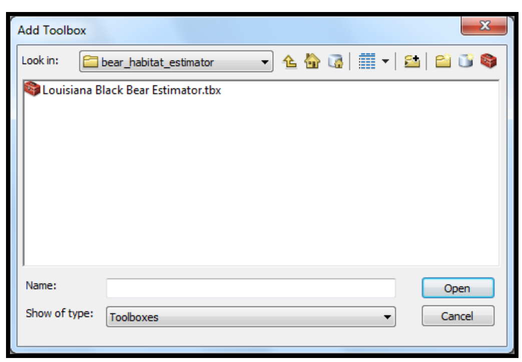
```
# Choose "properties", then click on the parameters tab
# click in the first empty row to begin entering parameters as shown below:
#
#                                                        Parameter Properties
#           Display Name                      Data type        Type      Direction  Multivalue
#  argv[1]  Working directory                  Folder        Required      Input       No
#  argv[2]  Summary_only                       Boolean       Optional      Input       No
#  argv[3]  Input polygon file                 Shapefile     Required      Input       No
#
# One of the next for options must be selected if "Summary_only" was not selected
#  argv[4]  Change to natural/forest           Boolean       Optional      Input       No
#  argv[5]  Change to natural/non-forest       Boolean       Optional      Input       No
#  argv[6]  Change to non-natural              Boolean       Optional      Input       No
#
# Roads may be added within the above shapefile.  New density is calcualted
#  argv[7] Roads                              Shapefile     Optional      Input      No
#
# Buffer size to be used if "Summary_only" was not selected, default set at 1500 m
#  argv[8] Buffer Size                        Linear Unit   Optional      Input      No


# Import system modules
import arcgisscripting, sys, string, os, shutil

# Create the Geoprocessor object
gp = arcgisscripting.create()

###gp.SetProduct("ArcView") # or "ArcEditor" or "ArcInfo"
##
### Set the overwrite option to true
gp.OverwriteOutput = 1

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/Desktop10.1/ArcToolbox/Toolboxes/Spatial Analyst Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/Desktop10.1/ArcToolbox/Toolboxes/Conversion Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/Desktop10.1/ArcToolbox/Toolboxes/Data Management Tools.tbx")
gp.AddToolbox("C:/Program Files/ArcGIS/Desktop10.1/ArcToolbox/Toolboxes/Analysis Tools.tbx")


# Script arguments...
```

Launching the Louisiana Black Bear Habitat Estimator:

1. Open an ArcGis 10.1 project. If ArcToolbox is not already open, open it by clicking on the red toolbox icon.



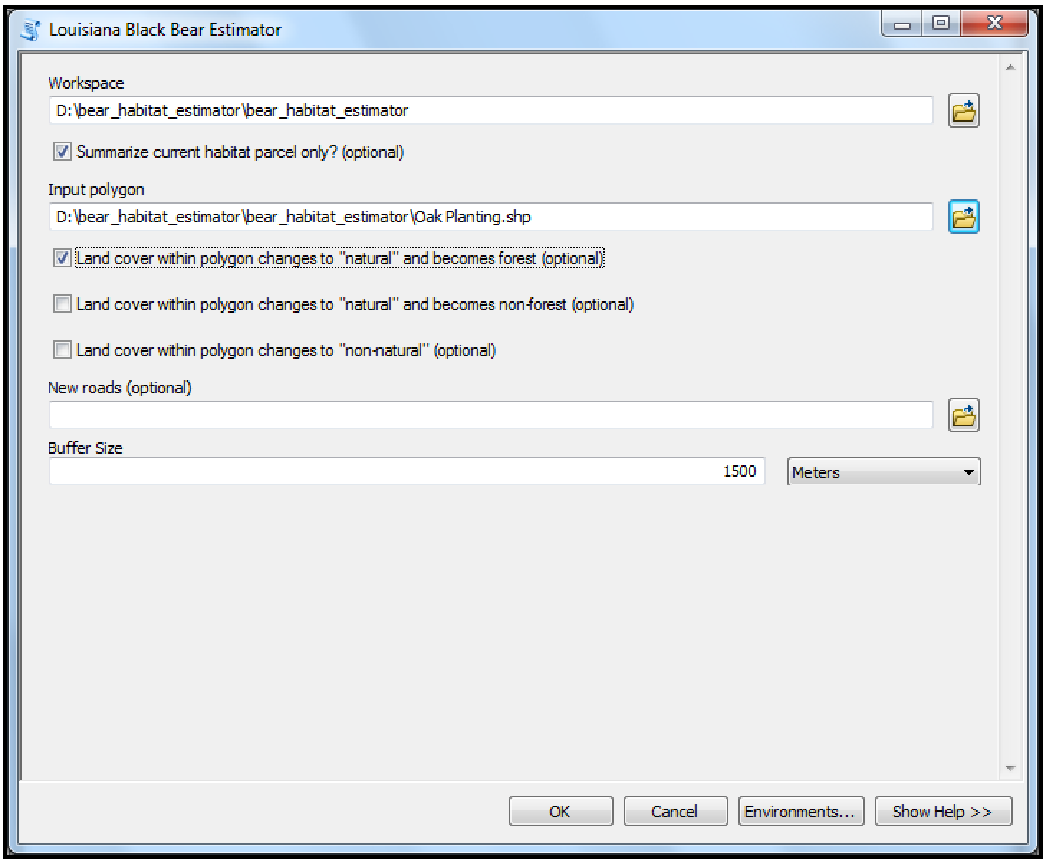
2. Right-click on any blank space in the window (see figure). Choose "Add Toolbox", and navigate to "**Louisiana Black Bear Habitat Estimator**" in the directory where you placed all the files from the flash drive.



3. In ArcMap™, click on the Customizes menu, click on Extensions, and make sure there is a check mark next to Spatial Analyst. (A spatial analyst license is required to run Louisiana Black Bear Habitat Estimator.)

3. USING THE LOUISIANA BLACK BEAR HABITAT ESTIMATOR

1. In ArcToolbox, double-click on the **Louisiana Black Bear Habitat Estimator**. Then double-click on the script icon with the same name. The following dialog box will appear:



2. **Workspace.** To specify the workspace, click on the folder button and navigate to the flash drive or to where you placed the folder from the flash drive. **Click only ONCE on the folder name, then click "<u>Add</u>".** (For example, click once on "*c:\ bear_habitat_estimator*" and then click "<u>Add</u>".)

3. **Summarize current habitat value of parcel only?** Check this box to calculate the current habitat value of your polygon. If you check this box, specify an input

polygon and leave the remaining dialog boxes blank. There is no buffer used during this calculation regardless of what the buffer size is in the dialog box.

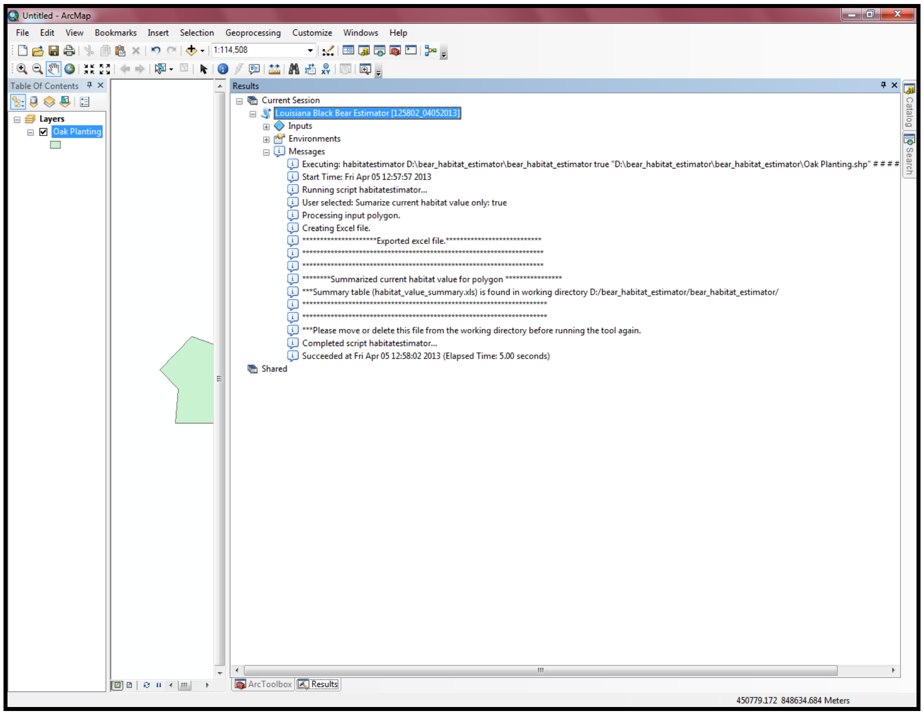
4. **Input polygon.** To choose your input polygon representing the boundaries of the land parcel, click on the folder button, select your shapefile, and click "Add".

5. **Options**. You now have several options from which to choose. Change land cover within the entire input polygon to 'natural-forest, natural-non-forest, not natural'. BEWARE: all of the polygon will change to what you choose. (See previous report for definitions of forest and non-forest)

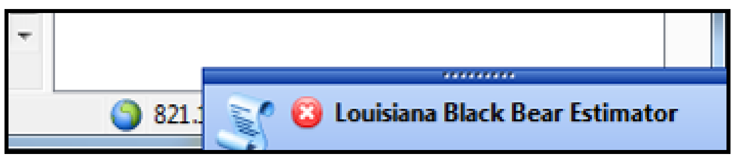
6. **Input roads (optional).** To choose your roads polyline file, click on the folder button, select the shapefile, and click "Add". If no new roads will be built, leave this blank.

7. **Specify larger study area? (optional).** Specify the size of the area for which you want to evaluate bear habitat. If you enter no value, the standard buffer distance of 1,500 m beyond the boundaries of your input polygon will be applied. If you desire evaluation of areas beyond this buffer distance, specify the additional distance of that buffer in meters.

8. Click on the box "OK". Depending on the speed of your computer and the size of your study area, the simulation process may take 5 minutes or longer. Larger study area sizes particularly increase processing time. Once the estimator starts, a status box will flash across the bottom of the ArcGis window. Do not be surprised if nothing seems to happen for many minutes. A green check mark will flash with a dialog box that says Louisiana Black Bear Estimator when the Utility is complete. The Results Tab will state that it completed successfully and remind you where the excel file of results is located. To view the log of the results, you can click on the Geoprocessing tab and select Results. The Messages tab will show you what the Utility is doing in real-time.



If the following appears:



An error occurred and you should look at the Results Tab in ArcGis to assess the problem. See *Troubleshooting*.

Output Files

1. After the program finishes running, the output of the simulation will be an ArcMap™ grid named "*FINALRESULT*". To view the *FINALRESULT* grid, add the layer file called *Final Results.lyr* to ArcMap™. If necessary, right click on the file named *Final Results.lyr* in ArcMap's table of contents to re-set the source to the *FINALRESULT* grid in your working directory.

2. The Excel file named *habitat_change_summary.xls* will contain a summary of habitat values and acreage changes.

4. TROUBLESHOOTING

a. You must make sure that all the grids needed to run the utility have statistics associated with them. View each grid in ArcCatalog by opening ArcCatalog, selecting any grid in your folder (water_den, rd_den, etc.) and selecting the preview tab. You are typically asked to build pyramids. Select "No" and the grid should properly appear in the preview window. This is the most common cause for errors in the running of the utility. If you see a display but it is all 1 color, open that grid in ArcGis and see if the values make sense. If there are negatives or all the values are the same, your grid will either need to be recopied or exported as a grid.

b. If you receive an error during your initial installation, the program may be having trouble locating the Arc Toolbox, as this can vary. For the program to operate appropriately it should be located at: C:\Program Files\ArcGIS\Desktop10.1\ArcToolbox\Toolboxes. If the Toolbox folder is located elsewhere, the estimator will have to be redirected:

   i. Open the hab_estimator.py file in notepad.
   ii. Find line "# Load required toolboxes...
   iii. Change the file location to the specifics of your computer on the next 4 lines and save the file. Manually change the extension to ".py" and reload the program.

c. If you receive error messages, especially those that say "*...file locked by another user*" or mention the words "*schema lock*", exit ArcMap™ and ArcCatalog™, and be sure that output files from previous simulations have been removed. Always close and re-open ArcMap™ after each time you run the estimator to prevent this error.

d. Ensure that the Spatial Analyst extension is turned on. (ArcMap™ Tools menu).

e. You must have ArcMap™ installed at the ArcInfo license level, rather than the less powerful ArcView license level.

f. Make certain that the output files are not currently open in ArcMap™ or Excel before running the estimator again.

g. Delete the output *FINALRESULT* grid or move them out of your working directory using ArcCatalog™ before running the estimator again. Also delete the output files named *habitat_change_summary.xls* and *habitat_change_summary.dbf.*

h. If you cancel the estimator's operation as it is running, you will need to delete the temporary workspace that stores the interim files. The temporary workspace is a folder called 'scratchWS' and is located in the working directory you specified.

i. Error messages will occur if any of the necessary files have been accidentally deleted from your working directory. Try copying the contents of the flash drive to your working directory again to ensure that all files are present.

j. Make sure there are no spaces in your folder names.

k. If you are still receiving error messages, start over by deleting the *bear_habitat_estimator* folder altogether and re-copying the contents of the CD to your hard drive.

l. Ensure that your input file is a polygon shapefile, not a polyline.

m. To view the log of the results as it is running or after a run, you can click on the "geoprocessing" tab and select "Results".